Towards Cognitive Enhancement of the Elderly: A UX Study of a Multitasking Motion Video Game

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Abstract

Cognitive impairments decrease the quality of life of the elderly. Earlier studies show multitasking *sedentary* video games are an effective intervention. However, little work has studied multitasking *motion* video games which can be more directly beneficial for overall wellbeing. This project investigates the efficacy of multitasking motion video games for the cognitive enhancement of the elderly. As a response to this situation, we developed a custom-made game called *Safari Move*. Here we report the initial step towards our goal in which we studied whether or not elderly people enjoy playing our game. Two important game elements were studied - skill balancing methods and controller types. Our results demonstrate that our participants enjoyed playing our game, and that they prefer manual over dynamic difficulty adjustment, and Microsoft Kinect over Gamepad. Future work will use neuroimaging and cognitive assessment tools to investigate the effectiveness of Safari Move to enhance cognitive function.

Author Keywords

Motion video games; Cognitive enhancement; Elderly; Game experience; Skill balancing; Game controller.

ACM Classification Keywords

H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

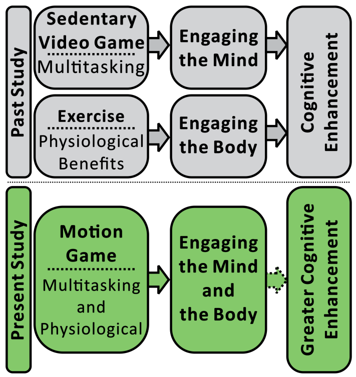

Figure 1: Situating with past work.

Cognitive Benefits of Exercise and Multitasking
Studies [1, 2] reveal that if a game is tailored to a specific cognitive deficit in the elderly, i.e., multitasking, that game leads to significant cognitive enhancement. Furthermore, strong evidence supports the finding that exercise enhances cognition from the physiological perspective by mediating the growth of new neuronal cells [5, 17]. This project combines the positive qualities of multitasking in video games and the physiological benefits of physical exercise in the form of a multitasking motion video game.

Introduction and Related Work

Issues related to the elderly have attracted a lot of attention due to the increasing aging population. All elderly people experience some degree of cognitive decline over time such as forgetfulness, lack of ability to focus, and dementia, which can have serious consequences on their general wellbeing. The good news is that research shows that even the brains of mature aged people can change, develop new neural pathways, or even reverse brain aging effects in response to various life experiences. This capacity for the brain to renew itself is called *Neuroplasticity* [11]. One related field that has attracted much attention is video games, given their general ability to engage users in prolonged and long-term training activities [9, 10].

Most cognitive enhancement work has focused on *sedentary* video games but little work has been done on *motion* video games which may produce more direct and healthier effects. Thus we developed a multitasking motion video game called *Safari Move* which combines the positive qualities of multitasking [1, 2] and exercise [5, 17] which have both been shown to induce neuroplasticity changes in the brain (see left sidebar and Figure 1).

Prior to full deployment of the game which can be costly, we ran an initial player experience (PX) study to determine whether the elderly enjoy playing our game. Aside from general engagement, we were also interested to determine the preferences of the elderly in two game elements, i.e., skill balancing and the type of game controller.

Skill balancing refers to a good adjustment of skill and challenge levels according to the *Flow* theory [7]. In Manual Difficulty Adjustment (MDA), players choose their preferred level of difficulty. However, players often have difficulty predicting their skill level. Furthermore, MDA usually supports a static difficulty level and as a result the game can get boring as a user's skill increases. A second method is Dynamic Difficulty Adjustment (DDA) by which algorithms automatically match challenges to the user's growing skill level in real-time. However, DDA often suffers from cold-start problems, and the possibility of getting stuck in a particular level of difficulty [16]. Recent work has studied the effect of skill balancing on player experience (PX) for young players [16] but not for the elderly.

Another open question is whether skill balancing is influenced by controller type. Recent work [8, 14] showed that despite lower performance, the elderly prefer to play using motion-based controllers. We built upon these work and investigated whether there is any interaction effect between skill balancing and controller types.

Specifically, our work asks the following five questions: (Q1) How do MDA and DDA affect the elderly PX? (Q2) How do Gamepad and Kinect affect the elderly PX? (Q3) Is there any interaction effect between skill balancing and controller types? (Q4) How do skill balancing and controller types affect the performance of the elderly? (Q5) Do the elderly prefer to play easy games or challenging games, just like young people? To clarify these questions, we assessed the PX of 20 elderly people.

Safari

Our general goal being to develop a game that is playable by the elderly, it should have low entry-level barriers and it should take into account the physical and mental limitations of elderly people. We also make sure that the mechanism of multitasking and exercise are tightly integrated into the gameplay. We therefore employed simple, enjoyable, stimulus-response gameplay. We designed a casual game called *Safari* (Figure 2) in two versions: *Safari Tap* using GamePad and *Safari Move* using Microsoft Kinect. We

Figure 2: Screenshots of *Safari Tap* (up) and *Safari Move* (bottom).

used a zoo theme because our design iterations showed that the elderly found it to be engaging.

To design a game that is both playable through body parts (i.e. exercise) and Gamepad, Safari uses the *Whac-A-Mole* mechanics where the goal is to feed animals as they pop out of their holes. Our participants commented that whacking animals is cruel so we changed the meaning of each response to 'giving apples' rather than 'whacking'. Participants were asked to press the corresponding buttons (Safari Tap) or move their corresponding body parts (Safari Move) to feed the animals when they saw them coming out of their respective holes. To allow the elderly to easily learn how to use the controllers, we mapped the Gamepad buttons and their body parts to the layout of the holes (e.g., the bottom-left hole was mapped to the left leg).

For multitasking, it can be induced when someone tries to perform two tasks concurrently, switch from one task to another, or perform two or more tasks in rapid succession. Thus, to support multitasking, we integrated a billboard on the left which randomly shows different shapes (e.g., square, triangle) in different colors (e.g., blue, green). When the sign is exactly a green triangle, players have to play differently. In *Safari Tap*, the player needs to first press the "Up" button before pressing the animals, whereas in the *Safari Move*, the player was instructed to first step forward, then move the body parts and after that come back to the main position to prepare for the next movement (see Figure 3 for example). Otherwise, the player just ignores the billboard and gives apples to the animals as usual. To give meaning to the multitasking, each button or body input will give water to the animals instead of apples. By switching attention between the animals and the billboard, we induced a task-switching paradigm [13] where the number of shapes and colors on the billboard can be tuned as challenge mechanics.

To promote mastery and a sense of competence, consecutive successful actions are counted and shown to the players (e.g., "*3 Combos!*") in real-time. "*Nice!*", "*Cool!*" and "*Great!*" were shown visually, when the player gets 5, 15 and 30 "*Combo!*", respectively. The player's performance is displayed at the bottom-left of the screen. Suitable background music and audio feedback were used in the game design.

MDA and DDA

We applied MDA and DDA methods for skill balancing. The design space of all challenge mechanics, e.g. time span for pressing the animals, time interval between set of animals, number of shapes and colors on the billboard, was investigated to define the level of difficulty. Pilot studies with a different set of ten users were conducted where different settings were played and performance was recorded. A model was created through mapping challenge mechanics with performances. Using the model, 75 sub-levels from easiest to hardest were generated. MDA was implemented using a menu interface to let users choose their desired levels before playing. The 75 sub-levels were categorized into five levels (i.e. 15 sub-levels in each level) including *Very Easy*, *Easy*, *Normal*, *Hard* and *Very Hard*.

For DDA, in general, the system increased one sub-level after a player performed an action correctly and it decreased one sub-level when the player missed an action or performed a wrong action. To avoid the cold-start problem at the beginning of gameplay (e.g., *Very Easy* level), a big increase (i.e, increase three sub-levels) and small decrease policy (i.e, decrease only one sub-level) was adopted. However, to keep challenge on the *Very Hard* level, a small

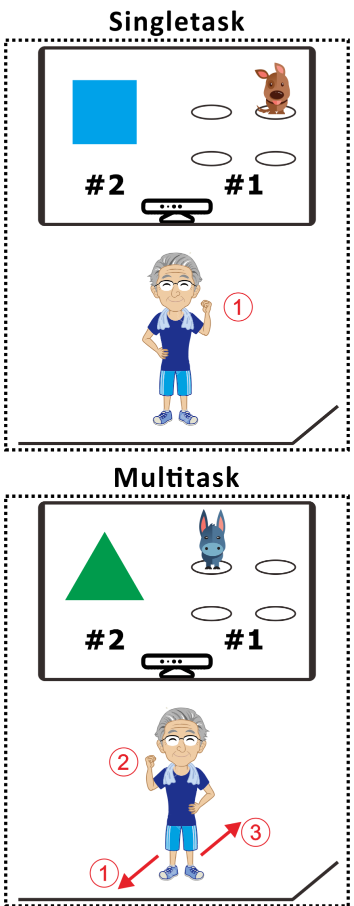

Figure 3: In the singletask, the player only moves the body parts according $\sharp$1. In the multitask, with the green triangle in $\sharp$2, the player is first required to step forward, then move the body parts according to $\sharp$1, and then step back to the original position.

increase (i.e., increase only one sub-level) and small decrease policy was used.

Experiment

To evaluate general enjoyment of our game, and to evaluate the effect of skill balancing methods and controller types, we conducted an experiment using a 2 x 2 within-subjects design. The '*Skill Balancing*' was within-subjects, comparing the DDA and MDA. The '*Controller Type*' was within-subjects, asking the participant to play with GamePad and Kinect respectively.

Participants

20 elder persons (5 females) aged 65-85 (*M*=71.5, *SD*=6.3) were recruited. None suffered from any physical or mental impairment. Three participants reported having had experience with video games. However, none had experienced motion-based games. Each participant was paid $20.

Apparatus

Safari was built using Unity 5.0.0 and C#. The Microsoft Kinect (v1) and an Xbox 360 controller were used in both motion and sedentary conditions, respectively. The games ran on a 2 GHz Intel Xeon CPU PC with Windows 8. A 40" Phillips LCD screen with a resolution of 1920 by 1080 was used.

Task and Procedure

Participants signed a letter of consent and were informed about the goal of the study. Demographic information including health background and gaming expertise was gathered. Participants were taught the game rules before playing a 10-minute warm up round. They were situated approximately 1.7 meters away from the display in both sedentary and motion conditions.

In total, four game conditions were played: *MDA-GamePad*, *DDA-GamePad*, *MDA-Kinect* and *DDA-Kinect*. To avoid learning effects and fatigue problems, conditions were counterbalanced using a Latin square. Participants played each game in three rounds of 5-minutes with 3-minutes rest between the rounds. In *MDA-GamePad* and *MDA-Kinect*, participants set the level of difficulty before each round. After each game, participants completed questionnaires. Each game including questionnaires lasted about 50 minutes. The experiment was conducted within two days. A short semi-structured interview was conducted at the end of the experiment.

Measures

The overall performance and the level of difficulty were logged. *Affect* was measured using the *Positive and Negative Affect Schedule* (PANAS) [6] which was completed by the player before and after each condition. PANAS was rated on a 5-point Likert-scale. *Interest-enjoyment* and *effort-importance* dimensions from the *Intrinsic motivation inventory* (IMI) [12] were used to assess motivation. *Autonomy*, *competence*, *presence* and *intuitive controls* dimensions from the *Player Experience of Need Satisfaction* (PENS) [15] were used to measure needs. Both IMI and PENS were completed after each condition and rated on a 7-point Likert-scale.

Results

The Kolmogorov-Smirnov test and homogeneity of variance using Levene's test were performed for parametric evaluation. Cronbach's-α was reported to show the consistency of the scale items for each questionnaire. We analyzed PX comparing *Controller Type* and *Skill Balancing* using repeated-measures analysis of variance (RM-ANOVA) and Mauchly's sphericity tests. Post hoc tests with Bonferroni correction were used for learning effect analysis. Significance was set at $\alpha = 0.05$.

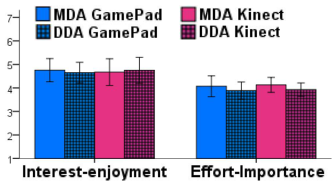

Figure 4: Means (95% Confidence Interval) for IMI; Cronbach's-α is 0.93 and 0.78 for *interest-enjoyment* and *effort-importance*, respectively.

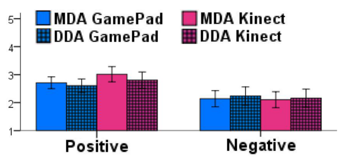

Figure 5: Means (95% Confidence Interval) for PANAS; Cronbach's-α is 0.80 and 0.89 for *positive affect* and *negative affect*, respectively.

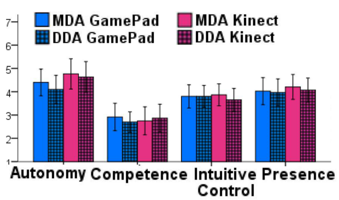

Figure 6: Means (95% Confidence Interval) for PENS; Cronbach's-α is 0.90, 0.83, 0.88 and 0.95 for *autonomy*, *competence*, *intuitive control* and *presence*, respectively.

Motivation (IMI)
Figure 4 shows IMI subscales. There is no main effect in either *Controller Type* or *Skill Balancing* on *interest-enjoyment* and *effort-importance*. However, there is a trend with MDA showing higher motivation (effort-importance) than DDA ($p = 0.09$). We also did not find any interaction effect in *Controller Type* $\times$ *Skill Balancing*.

Affect (PANAS)
Figure 5 shows PANAS subscales. There is a main effect in *Controller Type* ($F_{1,19} = 6.09$, $p < 0.023$, $\eta^2 = 0.243$) on *positive affect*. The players experienced a higher *positive affect* for the Kinect ($M = 2.91$, $SD = 0.60$) than for the GamePad ($M = 2.65$, $SD = 0.47$). There is also a main effect in *Skill Balancing* ($F_{1,19} = 7.68$, $p < 0.012$, $\eta^2 = 0.288$) on *positive affect*. The MDA ($M = 2.86$, $SD = 0.53$) has higher *positive affect* than the DDA ($M = 2.70$, $SD = 0.57$). Overall, *positive affect* is significantly higher than *negative affect* ($F_{1,38} = 15.24$, $p < 0.001$, $\eta^2 = 0.28$). No main effect was found for *negative affect*. There is no interaction effect in *Controller Type* $\times$ *Skill Balancing*.

Need Satisfaction (PENS)
Figure 6 shows PENS subscales. There is a main effect in *Controller Type* ($F_{1,19} = 4.32$, $p < 0.05$, $\eta^2 = 0.18$) on *autonomy*. The results indicate the sense of *autonomy* is higher for the Kinect ($M = 4.70$, $SD = 1.38$) compared to the GamePad ($M = 4.25$, $SD = 1.25$). However, there is only a trend effect in *Skill Balancing* ($p = 0.14$). The MDA ($M = 4.58$, $SD = 1.30$) has a higher score of *autonomy* compared to the DDA ($M = 4.36$, $SD = 1.36$). There is no main effect on other subscales. Also, there is no interaction effect in *Controller Type* $\times$ *Skill Balancing*.

Performance
Results are shown at Figure 7. There is a main effect in *Controller Type* ($F_{1,19} = 45.67$, $p < 0.001$, $\eta^2 = 0.70$). *Performance* for the Kinect ($M = 77.50$, $SD = 15.61$) is higher than for GamePad ($M = 62.14$, $SD = 16.41$). There is also a main effect in *Skill Balancing* ($F_{1,19} = 175.25$, $p < 0.001$, $\eta^2 = 0.90$). The MDA ($M = 81.64$, $SD = 16.02$) *performance* is notably higher than the DDA ($M = 57.99$, $SD = 9.53$). There is no interaction effect in *Controller Type* $\times$ *Skill Balancing*.

Learning effect
Figure 8 shows the learning effect analysis of difficulty level for MDA. There is a main effect in *Order* ($F_{2,76} = 71.880$, $p < 0.001$, $\eta^2 = 0.65$, Mauchly not sig.). Post hoc comparisons revealed a significant difference between all pairs - the first ($M = 2.07$, $SD = 0.94$), second ($M = 2.90$, $SD = 1.08$) and the third ($M = 3.75$, $SD = 1.23$) rounds (all with $p < 0.001$).

Figure 9 shows the learning effect analysis of performance. Results indicate a main effect in *Order* ($F_{2,158} = 17.440$, $p < 0.001$, $\eta^2 = 0.18$). Post hoc tests show third round performance ($M = 63.9$, $SD = 20.9$) is significantly lower than ($p < 0.001$) first round performance ($M = 73.6$, $SD = 19.7$), and lower than ($p < 0.001$) second round performance ($M = 71.9$, $SD = 18.9$). But there is no difference between first and second round performances.

Discussion
Our work explores the PX of elderly players in order to answer our five research questions.

(Q1) We found that the elderly have higher motivation, positive affect, and autonomy when they use MDA over DDA. This is counterintuitive but one possible explanation is that MDA gives users a sense of freedom to choose their comfortable level of difficulty.

(Q2) We found our elderly players preferred to play with

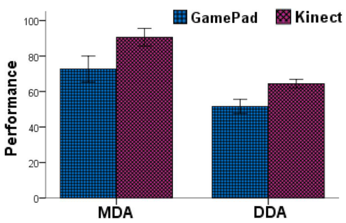

Figure 7: Means (95% Confidence Interval) for Performance.

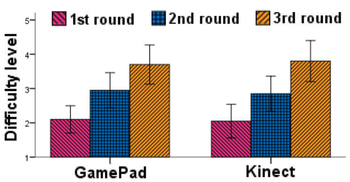

Figure 8: Learning effect. Means (95% Confidence Interval) for Difficulty level using MDA.

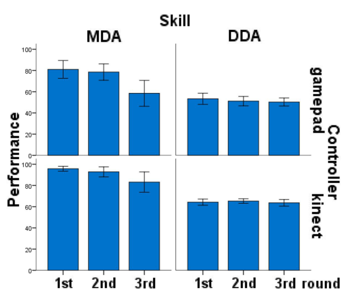

Figure 9: Learning effect. Means (95% Confidence Interval) for Performance.

Kinect over Gamepad. A higher positive affect and higher autonomy were reported for Kinect over GamePad. This is consistent with previous findings for young players [3, 4] and it confirms that moving itself is fun.

(Q3) We found no interaction effect between skill balancing and controller, suggesting that there is no dependency between the two constructs.

(Q4) Performance for Kinect is higher than for GamePad, in addition, we have double checked that there is no difference in the level of game difficulty between these two controller types. What we observed is that the elderly can learn and perform body input tasks better than they can perform with Gamepad input actions, probably because body input feels more natural. On the other hand, the elderly perform better with MDA than DDA. However, it should be noted that this result is expected because most participants selected lower difficulty in MDA compared to the difficulty set by the DDA algorithms.

(Q5) Log files related to difficulty levels show that the selected levels of difficulty chosen using MDA are lower than those of DDA. However, learning effect analysis for performance and difficulty level using MDA shows that the elderly surprisingly increase the level of difficulty between rounds even when performance goes down. We therefore conclude that it is a misconception that the elderly do not like to be challenged. This data may also explained why MDA is preferred over DDA, i.e., our DDA algorithm may have overestimated players' skill as we can see that MDA difficulty is lower than those of DDA, and thus may negatively affect the PX. Another explanation is that while MDA supports a sense of progress through manual adjustment of the difficulty, DDA lacks in those aspect as players have no way to know which difficulty they are currently playing and thus may not able to know whether they are improving or not.

Overall, our game seems to be engaging and suitable for the elderly in prolonged and long-term training. In the future we will conduct an interventional study to investigate the efficacy of Safari on cognition. We hypothesize that using body movements to perform multitasking will have a greater effect on cognition, compared to multitasking using sedentary video games. We will use neuroimaging and cognitive assessment tools to investigate long-term training effect of the multitasking motion video games.

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References

[1] Joaquin A Anguera, Jacqueline Boccanfuso, James L Rintoul, Omar Al-Hashimi, Farhoud Faraji, Jacqueline Janowich, Eric Kong, Yudy Larraburo, Christine Rolle, E Johnston, and others. 2013. Video game training enhances cognitive control in older adults. *Nature* 501, 7465 (2013), 97–101. http://dx.doi.org/10.1038/nature12486

[2] Chandramallika Basak, Walter R Boot, Michelle W Voss, and Arthur F Kramer. 2008. Can training in a real-time strategy video game attenuate cognitive decline in older adults? *Psychology and aging* 23, 4 (2008), 765. http://dx.doi.org/10.1037/a0013494

[3] Nadia Bianchi-Berthouze. 2013. Understanding the role of body movement in player engagement. *Human–Computer Interaction* 28, 1 (2013), 40–75. http://www.tandfonline.com/doi/abs/10.1080/07370024.2012.688468

[4] Max Birk and Regan L Mandryk. 2013. Control your game-self: effects of controller type on enjoyment, motivation, and personality in game. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 685–694. http://dx.doi.org/10.1145/2470654.2470752

[5] Yu-Kai Chang, JD Labban, JI Gapin, and Jennifer L Etnier. 2012. The effects of acute exercise on cognitive performance: a meta-analysis. *Brain research* 1453 (2012), 87–101. http://dx.doi.org/10.1016/j.brainres.2012.02.068

[6] John R Crawford and Julie D Henry. 2004. The Positive and Negative Affect Schedule (PANAS): Construct validity, measurement properties and normative data in a large non-clinical sample. *British Journal of Clinical Psychology* 43, 3 (2004), 245–265. http://onlinelibrary.wiley.com/doi/10.1348/0144665031752934/abstract

[7] Mihaly Csikszentmihalyi. 1990. Flow: The Psychology of Optimal Experience. *New York (HarperPerennial)* (1990).

[8] Kathrin M Gerling, Kristen K Dergousoff, and Regan L Mandryk. 2013. Is movement better?: comparing sedentary and motion-based game controls for older adults. In *Proceedings of Graphics Interface 2013*. Canadian Information Processing Society, 133–140. http://dl.acm.org/citation.cfm?id=2532129.2532153

[9] C Shawn Green and Daphne Bavelier. 2003. Action video game modifies visual selective attention. *Nature* 423, 6939 (2003), 534–537. http://www.nature.com/nature/journal/v423/n6939/full/nature01647.html

[10] Simone Kühn, T Gleich, RC Lorenz, Ulman Lindenberger, and Jürgen Gallinat. 2014. Playing Super Mario induces structural brain plasticity: gray matter changes resulting from training with a commercial video game. *Molecular psychiatry* 19, 2 (2014), 265–271. http://dx.doi.org/10.1038/mp.2013.120

[11] Eleanor A Maguire, Katherine Woollett, and Hugo J Spiers. 2006. London taxi drivers and bus drivers: a structural MRI and neuropsychological analysis. *Hippocampus* 16, 12 (2006), 1091–1101. http://dx.doi.org/10.1002/hipo.20233

[12] Edward McAuley, Terry Duncan, and Vance V Tammen. 1989. Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: A confirmatory factor analysis. *Research quarterly for exercise and sport* 60, 1 (1989), 48–58. http://dx.doi.org/10.1080/02701367.1989.10607413

[13] Stephen Monsell. 2003. Task switching. *Trends in cognitive sciences* 7, 3 (2003), 134–140. http://dx.doi.org/10.1016/S1364-6613(03)00028-7

[14] Tan Phat Pham and Yin-Leng Theng. 2012. Game controllers for older adults: experimental study on gameplay experiences and preferences. In *Proceedings of the International Conference on the Foundations of Digital Games*. ACM, 284–285. http://dx.doi.org/10.1145/2282338.2282401

[15] Scott Rigby and Richard Ryan. 2007. The Player Experience of Need Satisfaction (PENS): An applied model and methodology for understanding key components of the player experience. *Retrieved from immersyve. com/PENS_Sept07. pdf* (2007).

[16] Jan D. Smeddinck, Regan L. Mandryk, Max V. Birk, Kathrin M. Gerling, Dietrich Barsilowski, and Rainer Malaka. 2016. How to Present Game Difficulty Choices?: Exploring the Impact on Player Experience. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 5595–5607. http://doi.acm.org/10.1145/2858036.2858574

[17] Gao-Xia Wei, Ting Xu, Feng-Mei Fan, Hao-Ming Dong, Li-Li Jiang, Hui-Jie Li, Zhi Yang, Jing Luo, and Xi-Nian Zuo. 2013. Can taichi reshape the brain? A brain morphometry study. *PLoS One* 8, 4 (2013), e61038. http://dx.doi.org/10.1371/journal.pone.0061038